bility, or frequency of its occurrence, P, is given by the equation:[5]

$$P = ke^{-h^2 v^2}$$

where h and k are constants.

If the law of probability does actually govern the distribution of the velocities of the different winds, the graph of Figure 3 must conform to the above general equation. A convenient method of determining this is by means of what is known as "arithmetic probability paper," whereon a probability curve, or curve of frequency, when plotted, will appear as a straight line.[6]

The frequency of east and west component winds of different speeds as found by kite and pilot-balloon records has therefore been replotted on probability paper and the result is shown in Figure 4. The points all lie remarkably closely along a straight line, the greatest deviation in observed frequency being 2.5 per cent, while the deviation in general is less than 1 per cent.

For this particular route, therefore, we have experimental evidence that the probability of occurrence of an east or west wind component of given speed may be predicted with surprising accuracy, by the law of probability, from the observed frequency of winds of other speeds. If this relationship between the velocity of a free-air wind and the probability of its occurrence can be shown to have general application for other routes as well, a powerful method is disclosed for the prediction of winds of different speeds when sufficient data are at hand to determine the trend of the probability curve. A preliminary examination of free-air wind data for other parts of the country indicates the correctness of this hypothesis.

In the present instance the winds, as determined from an increasing number of air mail flights, tend to approach more and more closely the winds as found by kite and pilot balloon observations. This is exactly what we should expect if the actual winds (as would be disclosed from an indefinite number of observations), really do vary in accordance with the law of probability.

SUMMARY AND CONCLUSIONS

1. An extension of the analysis of air mail records to cover two consecutive years of operation between New York and Chicago indicates that the winds as determined in the previous analysis from more limited data are substantially correct.

2. In general, the winds determined from an increasing number of flight records tend to conform more closely to the winds as found by kite and pilot balloon observations. The tendency is particularly evident in the determination of the wind factor.

3. A theoretical explanation of this improved agreement is suggested by the resemblance of the wind graph to a probability curve. The frequency of occurrence of winds of different speeds, as shown by aerological observations, is found to agree remarkably closely with the probability of such occurrence as predicted by the law of probabilities. This agreement suggests that the distribution of the velocities of free-air winds may be found in general to be governed by the probability law, in which case a powerful method is disclosed for predicting the frequency of a given wind speed when complete information is not at hand.

4. An interesting improvement in the general performance of the air mail planes is revealed by an increase of several miles per hour in the average cruising speed. This is indicative of the type of improvement which may be expected in an air transportation service as experience in operation is accumulated.

5. In view of the importance of an accurate knowledge of winds along routes where regular aircraft operations are likely to be initiated in the near future, the above results emphasize again the urgent need for a material extension of aerological investigations to cover all parts of the country.

[5] Merriman, Mansfield. Method of Least Squares. New York, 1915, p. 25

[6] For a discussion of the construction and use of this paper, see "Storage to be Provided in Impounding Reservoirs for Municipal Water Supply," by Allen Hazen. Trans. of Amer. Soc. of Civil Engineers, vol. 77, pp. 1539-1667, 1914; also, "The Element of Chance in Sanitation," by George C. Whipple. Journ. Franklin Inst., vol. 182, pp. 37-59, 205-227, 1916.

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RESULTS OF MEASUREMENTS OF SOLAR RADIATION AND ATMOSPHERIC TURBIDITY OVER THE ATLANTIC OCEAN AND IN ARGENTINA.—PRELIMINARY REPORT

By Dr. FRANZ LINKE

[Translated from manuscript text in German by W. W. Reed, Weather Bureau Washington, D. C., January 7, 1924]

1. *Data on the expedition.*—April 5, 1923, departure from Hamburg on the *General San Martin*; May 2, arrival at Buenos Aires; beginning of May to the beginning of July, journeys in Argentina; July 15, departure from Buenos Aires on the *Hindenburg*; August 15, arrival at Hamburg.

2. *Instruments.*—Universal actinometer of Hartmann & Braun of Frankfort on the Main, made according to special plans with a red-glass filter having a thickness of 3.02 mm. (Schott F. 4512) and range of transmissibility from 600 to 2,000 $\mu\mu$. Incandescent-lamp photometer with sodium cell of Günther & Tegetmeyer, Brunswick, with Wulf's bifilar electrometer and condensers of Siemens & Halske having capacity of 2, 0.5, and 0.1 microfarads. Blue scale for the estimation of sky color (mixture of white and Prussian blue) issued by the Unesma, Leipzig. Portable aspiration psychrometer of R. Fuess, Steglitz.

Previous to the departure from Hamburg, frequently in Argentina, and after the return from the expedition the actinometer was compared with an Ångström compensation pyrheliometer that had been adjusted to the revised (1913) Smithsonian scale by W. Marten at Potsdam. Unfortunately the condensers, which are necessary for incandescent-lamp radiation measurements with electrometers (galvanometers of requisite sensitiveness are not practicable on expeditions), gradually lose their state of insulation in the Tropics, so that great difficult is met with in the work.

3. *Methods of observation.*—Measurements were made only when the sun was unquestionably free of cloud and at every favorable time of the day. These were carried out more frequently in the mornings and evenings; during the midday hours long interruptions occurred. The apparatus for measuring radiation was exposed on shipboard on the roof of the pilot house on a table having Cardan's method of suspension (swinging table). All observations were made by me. At each reading the altitude of the sun was determined with the sextant. Observations of air pressure, temperature, and relative humidity were made several times daily. On the outward and on the return voyage when the sun was at its zenith position measurement was made of sky brightness for the spectrum range of the sodium cell (maximum sensitiveness about 360 $\mu\mu$.

The blue scale contained 8 color tones from white to ultramarine blue, and estimation was made to halves of the scale. No. 3 was white; No. 10, ultramarine blue.

The deepest blue (No. 9) was observed in La Quiaca at the boundary between Argentina and Bolivia, about 3,700 meters above sea level.

4. *Methods of calculation.*—The air mass (m) through which radiation passed was determined, for the measured altitude of the sun, from Bemporad's table with reduction to a pressure of 760 mm. The turbidity factor (T) was measured according to the extinction formula [1] developed by me on the basis of a solar constant value of 1.932, taking into consideration the earth's solar distance. From the observations with the actinometer and the photometer there were interpolated, as far as the observations might permit, both the values for m = 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 6.0, 8.0, and 10.0, and also, with good daily series, those for the different hours of the day. The interpolation was made graphically on the logarithmic paper of Schleicher & Schull, No. 367½ ST. K. For the zones and points designated in Table 1 mean values were derived from these interpolated values in the usual way.

TABLE 1.—*Radiation intensity, turbidity, and sky color*

	Radiation intensity		Turbidity factor T [3]	Absolute humidity (e)	Blueness of sky (scale 3–10)	Part of turbidity factor due to dust, etc.
	m=1 cal.	m=3 cal.				
				mm.		
Dunkelmeer [1]	1.126	0.527	4.22	18.1	4.7	2.61
Calm zone	1.332	0.794	2.91	19.3	5.7	1.20
North Temperate Zone	1.393	0.882	2.56	9.7	5.7	1.21
South Temperate Zone	1.455	0.978	2.22	15.9	6.7	0.64
Northeast trades	1.455	1.004	2.14	14.2	6.6	0.50
Southeast trades	1.464	0.994	2.17	18.0	6.9	0.51
Argentina, cities [2]	1.481	1.021	2.08	6.0	6.5	0.86
Argentina, country [3]	1.590	1.213	1.52	3.0	7.1	0.41
Andes [4]	1.594	1.235	1.46	2.2	8.0	0.38
Bolivian plateau [5]	1.624	1.274	1.36	0.6	8.0	0.25

[1] Off Cape Verde Islands.
[2] La Plata and Mendoza.
[3] Pilar, near Cordoba.
[4] Puente del Fuca, 2,700 meters.
[5] La Quiaca, 3,600 meters.

5. *Results of measurements of total radiation.*—Columns 2 and 3 in Table 1 give the means of the interpolated radiation values in gram calories per square centimeter per minute for the zenith distance of the sun corresponding to m = 1 and m = 3; column 4 gives the turbidity factor for the solar altitude 19.3° (zenith distance, 70.7°). corresponding to m = 3, which is almost always reached in the Temperate Zone. Column 5 gives the mean absolute humidity (e) in mm. of vapor pressure; column 6, the blueness of the sky. It is noted how well the blue coloring runs opposite to the turbidity factor. However, in the upper portion of the accompanying Figure 1, the turbidity factor and the absolute humidity show no significant connection.

In the regions where the turbidity was evidently caused by dust and other dry particles (*trockener Dunst*) as on the *Dunkelmeer* [2] on account of the desert dust carried from the Sahara by the northeast trade wind, in the north Temperate Zone in the English Channel, and on the coasts of France and Spain on account of winds from the land, and in the cities of Argentina, the observations show a degree of turbidity which exceeds that corresponding to the degree of humidity . In the remaining regions *the turbidity factor increases 0.047e for each millimeter of vapor pressure.*

[1] Meteorologische Zeitschrift, 1922, S. 161 ff.
[2] *Dunkelmeer*, the name given to the portion of the Atlantic Ocean between the Equator and the Madeira Islands extending from the coast of Africa to 30° west longitude *Meyers Konversations-Lexikon*.

If we assume with J. Hann that the total water content of the atmosphere over a square meter of surface is on an average 2.3e or, as F. E. Fowle computes it in depth of water in cm., $w = \frac{2.3e}{10}$, then there results an increase in the turbidity factor amounting to 0.20w. This agrees fairly well with a purely theoretical calculation in my first paper on the turbidity factor,[3] in which on the basis of the data by F. E. Fowle relative to the transmission coefficients of dry air and of water vapor I found $T_w = 1 + 0.16w$ (formulas 8 and 10). Thus the influence of the water vapor contained in the air may be eliminated, and since for ideally pure air the turbidity factor is by definition equal to 1, the influence of the "dry" turbidity (dust, smoke, salt, etc.) may be estimated if we subtract from the observed turbidity factor the value $1 + 0.16w$, or $1 + 0.037e$. The part of turbidity due to particles of dust, etc. (*trockener Dunst*), thus appears in column 7 of Table 1. In Table 2, I add some observations of the turbidity factor for central Europe in order to make a comparison possible.

TABLE 2.—*Turbidity in central Europe*

Station	Observed turbidity (T)	Absolute humidity (e)	Part of turbidity due to dust, etc.
Frankfort on the Main:		*mm.*	
Winter	3.08	4.9	1.90
Summer	3.79	9.9	2.62
Kolberg:			
Winter	2.18	4.3	1.02
Summer	2.94	10.3	1.57
Potsdam:			
Winter	1.99	4.0	0.84
Summer	2.72	10.3	1.35
Taunus Observatory:			
Winter	1.40	4.0	0.25
Summer	2.66	8.6	1.34
Davos:			
Winter	1.64	2.5	0.59
Summer	1.78	7.6	0.50

The values obtained, showing the part played by the dry constituents in the degree of turbidity of the atmosphere, appear to me to be not improbable. In any case this first attempt to divide the turbidity into the effect of the absorption by water vapor and that of reflection by the larger, solid particles (dust, smoke, salt, etc.) encourages further steps in this direction.

6. *Results of the measurements of red radiation.*—The percentage of the radiation of a given spectrum region is dependent chiefly on the air mass through which the radiation passes. We must, therefore, consider the dependence of the *amount of red radiation* on humidity and other factors *for given air masses.* The lower portion of Figure 2 shows the dependence on vapor pressure measured at the ground.

It is noted that with air masses 1, 3, and 5 there exists almost the same relation, namely, *that with each millimeter of vapor pressure the percentage of red radiation decreases 0.2 per cent.* With greater air masses this value is apparently somewhat larger, but closely proportional to the percentage of red radiation. If we now eliminate this thus determined influence of water vapor on the amount of red radiation then no influence of the dust, smoke, etc. (*trockener Dunst*), is longer recognizable. *The "dry" turbidity appears to influence the percentage of red radiation very little or not at all.*

[3] Beiträge zur Physik der freien Atmosphäre, Band 10, S. 91 ff.

L. Gorczyński,[4] who by chance made radiation measurements at the same time while on a voyage to Siam and Java, wrote me that the Equator and south of it he found a lower percentage of red radiation, which he is inclined to view as a peculiarity of the Tropics. According to my measurements it is explained that this is only an effect of the greater amount of water vapor in the air.

7. *Results of the measurements of short-wave radiation.*—As already stated the constants of the incandescent-lamp photometer (with sodium cell) changed, unfortunately, many times. It seems, however, that this short-wave light is influenced chiefly by the dust, smoke, etc. (*trockener Dunst*), contained in the atmosphere and less by the water content. Yet I do not venture to give a numerical statement.

8. *Selective absorption by water vapor.*—From the results mentioned in section 6 it is also possible to determine the influence of selective absorption by water vapor, which lies almost entirely in the red and intra-red regions of the spectrum, on the water content. On the basis of the values for each wave length of extra-terrestrial radiation and for the transmission coefficients of pure air and of water vapor determined by C. G. Abbot and F. E. Fowle there may be found for each mass (m) a theoretical value for the dependence of the percentage of red radiation on the increasing amount of water vapor content, which (value), according to the values of a_w derived by E. F. Fowle, does not include, however, the selective absorption.

If we designate the red content by r_w when the water content is w (in cm.) and by r_0 when the air is dry, then $r_w - r_0 = \Delta r = \alpha w r_0$. Instead of this theoretical value α, which for $m=1$ would have the value 0.0097 we now find the value $\alpha' = 0.0145$, in which α' includes the *selective absorption*. The influence of the selective absorption (dark bands) on the percentage of red radiation is thus $\Delta r = (\alpha' - \alpha) w r_0 = 0.0048 w r_0$, in which r_0 with this red-glass filter has for $m=1$ the value 56.2, and for $m=3$ and $m=5$ the values 62.5 and 66.6, respectively. Unfortunately this result for Δr is uncertain by about 5 per cent.

9. *The daily march of the turbidity factor.*—Measurements of this kind extending over the whole day gave almost always an increase in turbidity factor till midday followed by a decrease till evening; on an average the values for the afternoon are greater than those for the forenoon, whence it follows that over the ocean also there occurs an increase during the day.

TABLE 3.—*Daily march of the turbidity factor (T.)*

	8 a. m.	9 a. m.	10 a. m.	11 a. m.	Noon	1 p. m.	2 p. m.	3 p. m.	4 p. m.
Dunkelmeer	3.43	3.50	3.68	3.77	3.83	3.84	3.83	3.80	3.73
North Temperate Zone	2.74	3.01	3.06	3.12	3.14	3.08	3.04	2.96	2.86
South Temperate Zone	2.22	2.36	2.54	2.61	2.65	2.60	2.55	2.46	2.30
Northeast trades	2.24	2.36	2.49	2.54	2.56	2.56	2.54	2.46	2.38
Southeast trades	2.28	2.44	2.52	2.55	2.57	2.56	2.52	2.40	2.25
Argentina, country	1.42	1.48	1.55	1.56	1.58	1.62	1.61	1.59	1.50
Andes, at 2,700 m	1.38	1.49	1.59	1.64	1.66	1.67	1.66	1.60	1.45
Bolivian plateau (3,600 m.)	1.35	1.42	1.42	1.42	1.44	1.46	1.45	1.44	1.38

If the afternoon values were not higher than those for the forenoon there would be the obvious assumption that the values of a_m cited by me in the calculation of T. (*loc. cit.*) were inaccurate since on the one hand they are based on the by no means certain values for extra-terrestrial radiation and transmission coefficient for pure, dry air calculated at the Astrophysical Observatory, Washington, and since on the other hand the selective absorption could not be taken into consideration for lack of data. So an explanation of the increase in turbidity around midday must be sought.

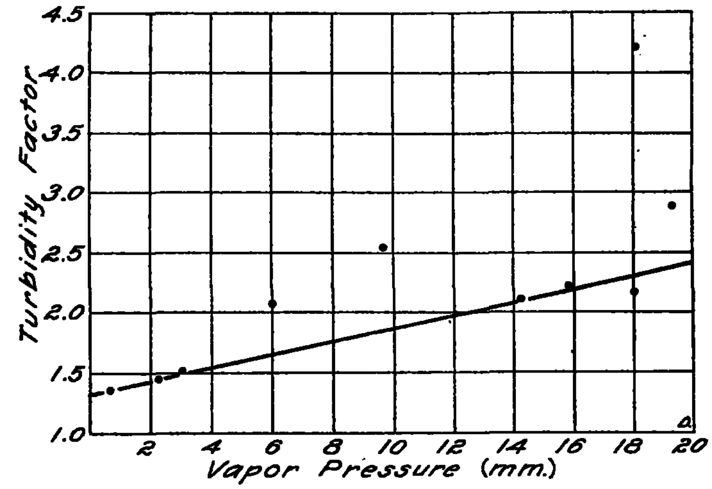

FIG. 1.—Dependence of the turbidity factor (T) on vapor pressure (e)

I have come to the conclusion that, as the result of the daily vertical convection in the lower air strata, there occurs at the upper limit of this convection stratum an increase in relative humidity and with it an increase in the size of the condensation nuclei whereby the latter

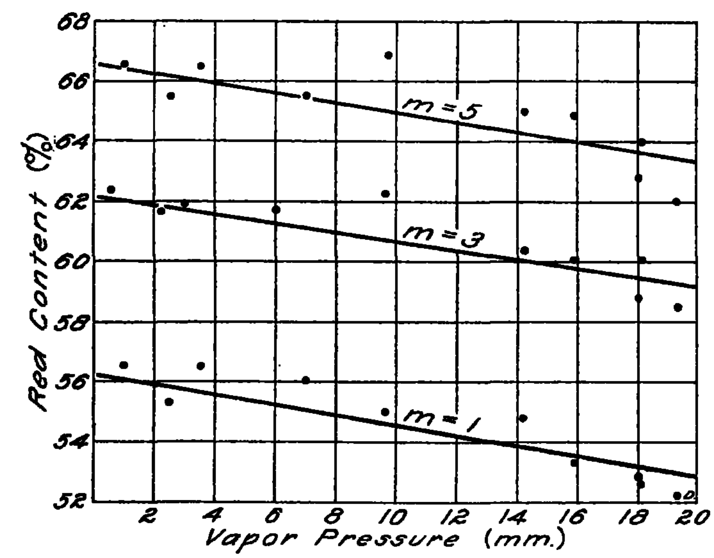

FIG. 2.—Dependence of the red content (r) of solar radiation on vapor pressure (e)

are enlarged beyond the wave length of light and thereafter totally reflect a portion of the direct solar radiation. This turbidity becomes recognizable even before the appearance of the clouds through the strong Tyndall effect of such dust-filled air which is near the point of saturation (pre-condensation stage).

I hope to be able to report in greater detail on this and other results in *Band 5, "Berichte des Meteoroligisch-*

[4] "Sur la diminution de l'intensité dans la partie rouge du rayonnement solaire, observée entre l'Europe et l'Equateur" (Comptes Rendus, Paris, 1923, p. 754). See also MO. WEATHER REV., October, 1923, 51: 528.

geophysikalischen Institutes," Frankfort on the Main, as soon as funds for publication are available. Only one result is to be given here.

10. *Relative values of sky radiation in the spectrum range of the sodium cell with the sun at the zenith.*—There are available four series of measurements which agree very well, so that the considerations previously mentioned do not hold for these relative values. The zone just at 30° altitude radiates least strongly. If we designate the value for this point by 100 then there appears the following distribution:

Altitude	5°	10°	15°	20°	25°	30°	35°	40°	45°	50°	55°	60°	65°	70°	75°	80°
Sky radiation	114	112	108	104	101	100	102	106	109	113	119	128	144	230	312	*500

*Approximate.

NOTE.—This expedition was supported by the *Ministerio de agriculture, Republica Argentina,* the Stinnes Steamship Lines, and the *Verein der Freunde des Taunus-Observatoriums,* Frankfort on the Main.

THE PHYSICAL-METEOROLOGICAL OBSERVATORY AT DAVOS, SWITZERLAND

551.501 (494)

By Prof. Dr. C. DORNO, Director of the Observatory

For several years the MONTHLY WEATHER REVIEW has from time to time published contributions from the director of the above-mentioned observatory, and in its bibliography has referred to his works. Recently there has been organized in connection with the observatory a medical research institute (Institute for Alpine Physiology and Tuberculosis Research), which, in collaboration with the observatory, will investigate the influence of the climate in high altitudes on both the healthy and the sick. Through this collaboration an institute for research unique not only in Switzerland, but almost in the whole world has been created, which has for its object the combating of that most terrible scourge of mankind, tuberculosis. In this work it will utilize the rich clinical material which is frequenting the world-renowned health resort of Davos. The director of the medical institute is Professor Loewy, the collaborator for many years of Professor Zuntz and he is at the same time in charge of the physiological laboratory. The pathologic-bacteriological department, which will be entirely independent, is still being enlarged and will soon be completed.

From the founding of the observatory in 1907, its investigations have been directed principally to radiation studies. These have included the radiation of the sun, and of the sky, and of both combined, as to their total energy and as to the energy of restricted spectral regions; also reflected radiation, and nocturnal radiation. Starting from the climatic points of view with the merely statistical problem of the quantities or intensities of the different kinds of rays that reach the place of observation, and their variation in intensity with the hour of the day, the season of the year, and the weather, the observatory soon enlarged its series of problems towards geophysics, and automatically to almost all the problems of atmospheric optics. The contributions to the climatic questions on the whole are given in the monograph published in 1911 by Friedr. Vieweg & Son, Brunswick, entitled "Studies on light and air of the high mountains," and containing the constants of radiation of Davos together with several years' records of the atmospheric-electrical elements and radioactive values. The former have been amplified and perfected in the subsequent years after the introduction of the photo-electric method. The Meteorologische Zeitschrift and the Physikalische Zeitschrift have published reports thereon. The program adapted to the "studies," which has also been described and discussed in other publications, has been followed in the researches of the radiation climate of other places, such as Kolberg, St. Blasien, recently also Arosa, Agra (Tessin), and even to a certain extent in the United States of North America. Atmospheric optics has claimed and obtained rightful recognition in the voluminous works "Phenomena of twilight and corona around the sun" and "Himmelshelligkeit, Himmelspolarisation und Sonnenintensität in Davos, 1911 bis 1918" which appeared in 1917 and 1919 in the Abhandlung des Preussischen Meteorologischen Institutes, Vol. V and Vol. VI. The latter work aims at uniformly comprehending the whole economy of atmospheric light, that is to say, establishing what has become of the incident solar radiation, and what sort of changes it has undergone with regard to intensity, polarization, and color. The years from 1919 to 1921 have been devoted to the perfection of recording methods on the basis of the methods employed only for individual measurements in the foregoing years. These efforts arrived at an almost complete success, as has been shown in "Progress in radiation measurements" published in the MONTHLY WEATHER REVIEW in 1922, according to which Davos is the first place in the world to continuously record the total exchange of heat by radiation during the course of a whole year.

After such successful work the observatory, founded and maintained by the director's own means, would have been forced to close in consequence of the depreciation of his German properties, had not, it may be said, all Switzerland—the Swiss Association for Naturalistic Research, Swiss Society for Climatology and Balneology, Swiss Red Cross, canton and community authorities, Cantonal Medical Association and others—(the subvention on the part of the Swiss Confederation is positively promised) undertaken to aid the observatory, and amplify it by a medical institute, as already described. Affiliated with the institute, but entirely free and independent with reference to its working methods, management, and name, as well as in its unaltered situation, the observatory exists independently by the side of the institute. Professor Dorno has been named an honorary member of the institute and member of the board. There is much to be hoped for in the future collaboration of meteorology, physics and physiology, more particularly as the place of observation, in the high mountains, is to be considered the most favorable for such combined investigations. Dorno's works published in the years 1922 and 1923, "About specific-medical climatology," "On the connection between the extension of the ultra-violet solar spectrum and the formation of pigment," and others, indicate the first directives to be followed by these works of collaboration, by the side of which the old aims of the observatory are being pursued in an unaltered manner.

About the foundation, organization, and the objects of the Institute of Physiology it may be briefly said: The board is composed of nine members, of whom five are to be medical men or naturalists. To the institute there is attached a scientific body giving advice and offering collaboration, being composed of professors of the Swiss universities, not only of medical men, but also representatives of the meteorological and physical faculty